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## EXECUTIVE SUMMARY

OPERATIONAL CONCEPTS  
FOR  
SELECTED SORTIE MISSIONS

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JOHN F. KENNEDY SPACE CENTER  
KENNEDY SPACE CENTER, FLORIDA



TRW

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EXECUTIVE SUMMARY

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OPERATIONAL CONCEPTS  
FOR  
SELECTED SORTIE MISSIONS

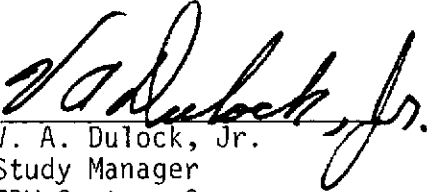
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Contract NAS10-8395

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
JOHN F. KENNEDY SPACE CENTER  
KENNEDY SPACE CENTER, FLORIDA

  
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## FOREWORD

The Operational Concepts for Selected Sortie Missions study was conducted by TRW Systems Group for the John F. Kennedy Space Center, Kennedy Space Center, Florida. The study was conducted from August 1973 to June 1974 under Contract NAS10-8395.

This document presents an executive summary of the study work and is submitted in accordance with the requirements stated in Section 7.4 of the contract statement of work. The complete study documentation consists of the following individual reports:

- Study Plan, 24981-F001-R0-00, August 1973
- Detailed Technical Report - Volume I, 24981-F002-R0-00, November 1973
- Detailed Technical Report - Volume II, 24981-F003-R0-00, February 1974
- Detailed Technical Report - Volume III, 24981-F004-R0-00, June 1974
- Narrative Report, 24981-F005-R0-00, June 1974
- Executive Summary, 24981-F006-R0-00, June 1974

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In addition to the Technical Management Team, the TRW study team received agency-wide guidance and overview by a NASA Steering Committee to assure optimum technical and program continuity and to maximize objectivity in concept development. The membership of the NASA Steering Committee is:

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## GLOSSARY

|        |  |
|--------|--|
| AFO    | Announced Flight Opportunity                         |
| C&W    | Caution and Warning                                  |
| CG     | Center of Gravity                                    |
| C/O    | Checkout   |
| CIU    | Computer Interface Unit                              |
| CONN   | Connect  |
| CTL    | Control  |
| C&D    | Controls and Displays                                |
| CV-990 | Convair 990 Aircraft                                 |
| DECU   | Data Exchange Control Unit                           |
| DMS    | Data Management System                               |
| DIU    | Digital Interface Unit                               |
| ECLS   | Environmental Control and Life Support               |
| EXPT   | Experiment   |
| EU     | Experiment Unit                                      |
| GSE    | Ground Support Equipment                             |
| HDWE   | Hardware   |
| INST   | Install  |
| IST    | Integrated Systems Test                              |
| IF     | Interface  |
| KSC    | Kennedy Space Center                                 |
| LPS    | Launch Processing System                             |
| MCF    | Maintenance and Checkout Facility                    |
| MSF    | Manned Space Flight                                  |
| MSOB   | Manned Spacecraft Operations Building (O&C Building) |
| O&C    | Operations and Checkout (MSOB)                       |
| OA     | Overall  |
| P/L    | Payload  |
| PP/L   | Primary Payload                                      |
| PI     | Principal Investigator                               |
| QR     | Quick-Reaction                                       |
| QRI    | Quick-Reaction Integration                           |
| QRIA   | Quick-Reaction Integration Activity                  |
| QRSL   | Quick-Reaction Spacelab                              |

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## GLOSSARY (Cont.)

|     |                            |
|-----|----------------------------|
| RF  | Radio Frequency            |
| R&I | Receiving and Inspection   |
| REQ | Requirement                |
| R&D | Research and Development   |
|     |                            |
| SID | Shuttle Integration Device |
| SA  | Space Available            |
| SL  | Spacelab                   |
| SU  | Support Unit               |
|     |                            |
| WTR | Western Test Range         |
| WBS | Work Breakdown Structure   |



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## 1.0 BACKGROUND INFORMATION

This project is the second of two studies which have investigated the "Quick-Reaction" approach to space experiment integration for the Shuttle era. The idea behind Quick-Reaction (QR) is that certain experiments are relatively simple to integrate with an appropriate experiment carrier; therefore, a payload carrying only this class of experiments could be integrated in a very short time period with a minimum of formalized procedures. It is felt that the resulting time and cost savings would significantly expand the Shuttle user market.

In the first study (NAS10-8043), the very successful Ames Airborne Science Program (CV-990 Program) was selected as a model. The Ames Program is characterized by quick response, extensive user participation, simplified procedures, operational flexibility, informality, and low cost. The objective, as shown in Figure 1, was to determine if these characteristics could be retained in the more severe operational environment of manned spaceflight.

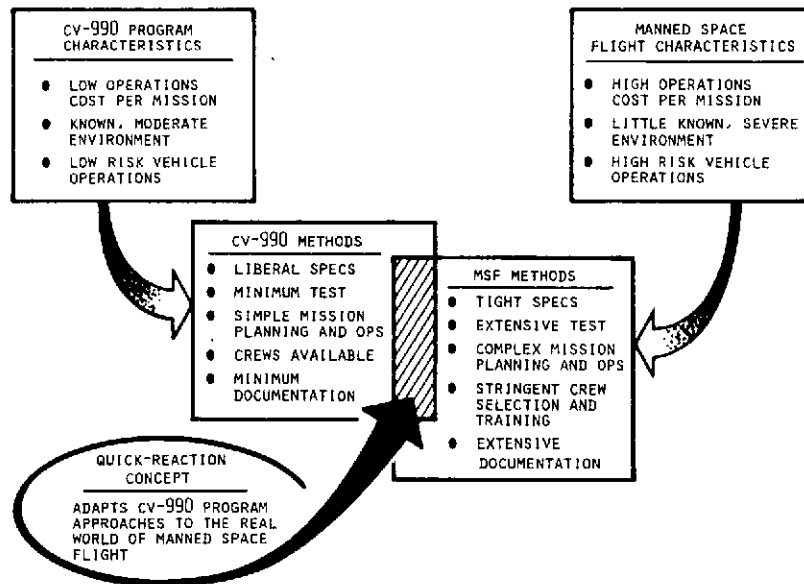


Figure 1. The Quick-Reaction Concept

To develop this idea, 24 representative simple-to-integrate experiments covering a variety of scientific disciplines were used. The Sortie Lab, then being defined by the Marshall Space Flight Center, was selected as the experiment carrier. A goal of 90 days turn-around from arrival of experiment hardware at the launch site to return of data to the user (Principal Investigator) was established. The overall cycle, from experiment concept to data return,

would be about one year. The payload integration activities would occur at the Shuttle launch site, and they would have to be compatible with Orbiter turn-around schedules.

Using these inputs, a Quick-Reaction integration concept was developed which preserves the principal advantages of the CV-990 Program and also meets the minimum safety and compatibility requirements of the Shuttle Program. The concept defines functional approaches to hardware integration, software integration, and mission integration. To support these integration activities, minimum essential programmatic functions, including configuration management, safety, reliability, quality control, and documentation were defined. This model then provided the basis for estimating manpower requirements, facilities requirements, organizational relationships, and launch site integration costs.

The principal features of this initial Quick-Reaction integration concept are:

- Experiments are limited to those which are simple to integrate; that is, relatively autonomous, no complex calibrations or alignments, and easy to operate. (With the trend toward increased hardware modularity, a growing number of experiments can be expected to fall in this category by the 1980s.)
- Five to ten experiments are flown per mission. Available integration time is the limitation.
- Experiment integration is performed by a small artisan team of highly skilled, versatile personnel working closely with the experimenter on the one hand, and the Sortie Lab maintenance crew on the other.
- Maximum use is made of existing facilities, shops, manpower, and other services available at the launch site.
- Software integration is simplified by use of a remote LPS terminal at the experimenter's home lab prior to his delivering the hardware to the launch site.
- Mission planning is simplified by complying with mandatory formal procedures where necessary, but allowing informal procedures where possible.
- A simplified documentation system, based on a User's Guide, reduces formal paperwork.
- A QR Mission Manager provides a single-point contact for the users.

The first study thus resulted in a feasible concept which satisfied the QR objectives. A follow-on study was then defined with these objectives:

- Investigate in more detail certain specific topics such as software integration, mission planning, and configuration management.

- Develop the QR concept to reflect the modular Spacelab configuration which had replaced the unitized Sortie Lab configuration baseline for the first study.
- Determine the impact of a second shuttle launch site on the QR concept.
- Develop an operational concept for QR space-available payloads

The remainder of this Executive Summary deals principally with the follow-on study.

## 2.0 SUMMARY OF STUDY CONCLUSIONS

### General conclusions:

- The short "concept-to-data-return" cycle and the user convenience of the Quick-Reaction concept are extremely desirable features and should be made available.
- The simplified ground operations and management concepts defined in this study indicate that a QR Spacelab mode is feasible. Furthermore, these concepts may have application to other planned missions.
- The baseline concept developed in this study provides a user-oriented, low-integration-cost service; however, the relatively high flight costs per experiment on a dedicated QR mission may discourage low-budget users.
- The "space-available" approach is feasible and is more suitable for low-budget users because flight costs are shared with the primary user.
- The commercial QR user, in either the dedicated or space-available mode, may encounter a launch support cost reimbursement environment similar to that currently faced by Special Interest Launch users today.

### Spacelab as a Quick-Reaction carrier:

- The split-module features of Spacelab result in more flexibility in the integration activities and allow selection of experiments from a larger market.

### Software integration:

- To meet QR objectives, processing and display of experiment data by the Spacelab Data Management System must be limited to that required for normal control of equipment.

### Mission planning:

- Quick-Reaction missions require an automated mission planning system (assumed to be operational in the Shuttle era).

- Iteration of final mission plans can occur as late as one month prior to launch.

#### Configuration management:

- Simplified configuration management is feasible for the Spacelab Experiment Unit and Pallets if rigid control is maintained only where safety and interface compatibility are involved.
- The Support Unit and other operational flight hardware should be controlled in the same manner as the Shuttle itself.

#### Documentation:

- The experimenters' involvement in documentation can be made very simple and informal by means of a Quick-Reaction User's Guide.
- Exchange of documentation between the QR activity and other support activities will be essentially the same as for other Shuttle users.

#### Integration alternatives:

- Performing the QR integration at any of several alternative locations has minimal impact on cost and schedule.
- Performance and management objectives are best met by accomplishing all integration at a single location.

#### Space Available concept:

- The current traffic model indicates that there are enough missions with space available for a QR experiment carrier to confirm this concept as a viable alternative mode of operation.
- The opportunity for sharing flight costs with the primary user makes this mode attractive to low budget users.

### 3.0 QUICK-REACTION OPERATIONAL CONCEPT UPDATE

The principal areas in which the baseline operational concepts were developed are as follows:

- |                           |                              |
|---------------------------|------------------------------|
| • Technical planning      | • Management system concepts |
| — Functional requirements | — Requirements management    |
| — Functional flows        | — Configuration management   |
| — Facility, GSE, and      | — Documentation              |
| manpower requirements     | — Work Breakdown structure   |
| • Technical concepts      | — Organization               |
| — Hardware integration    |                              |
| — Software integration    |                              |
| — Mission integration     |                              |
| — Equipment pool          |                              |

### 3.1 SPACELAB AS A QUICK-REACTION CARRIER

The Spacelab configuration used for this study is shown in Figure 2. The Support Unit (SU) houses the Spacelab operational subsystems. The subsystems for the Experiment Unit (EU) and Pallets are essentially extensions of the SU subsystems. For example, the thermal control subsystem operates in the SU, but the EU/Pallet contain piping and cold plates to serve the experiments. Experiment hardware is located in the EU or on the Pallets, as appropriate. The SU, the EU, and Pallet section are each about 10 feet long.

Assumptions and guidelines used for analysis purposes include:

- Two Quick-Reaction flights per year.
- The launch center is the owner/operator of the Quick-Reaction EU/Pallet.
- The launch center maintains the SU.
- The Spacelab maintenance and checkout station, the experimenter's laboratories, and the EU/Pallet work stations are located in the Operations and Checkout (O&C) building at KSC.

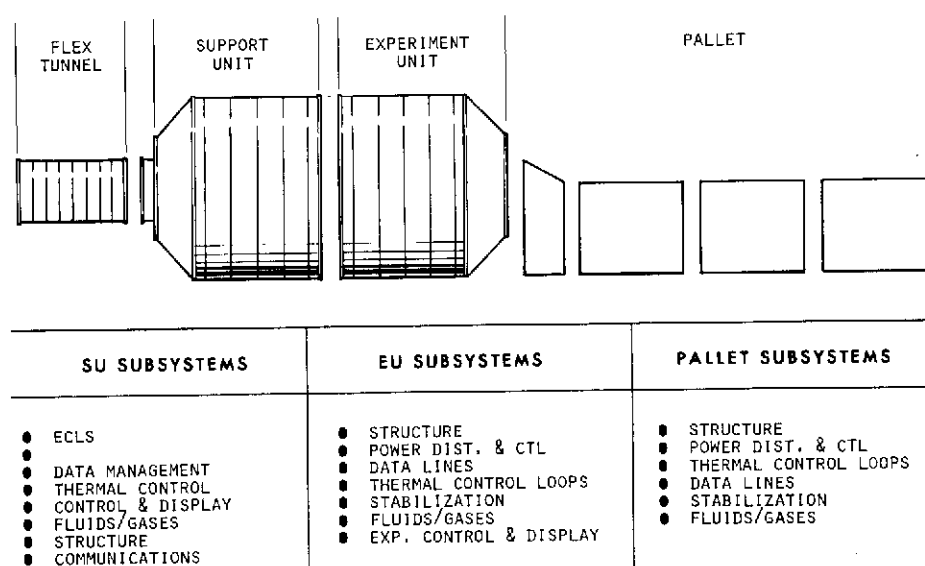


Figure 2. Spacelab Configuration Used for This Study

The principal feature of the split-module Spacelab is that it allows the experiment integration activities to be decoupled from the processing of operational flight hardware. Figure 3, a top-level, time-based functional flow diagram of the ground operations, shows off-loading of the QR Spacelab from the Orbiter immediately after post-landing operations. The SU and EU are demated, and the SU is processed for flight with another (non-QR) EU. The Quick-Reaction EU/Pallet are processed separately for the next QR flight. As

the diagram shows, the EU/Pallet processing does not become critical until the final 17 days, during which the EU/Pallet are integrated with an SU and the Orbiter.

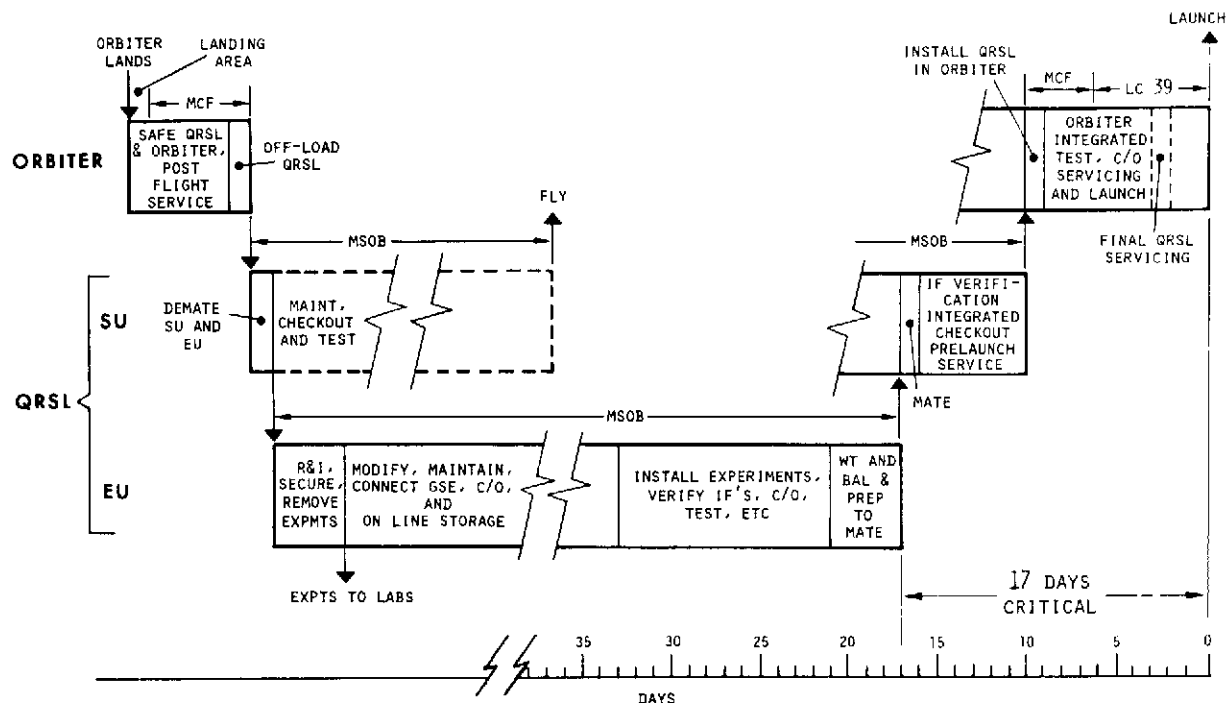


Figure 3. Quick-Reaction Spacelab Ground Operations Timeline

Detailed development of the functional flow identified all specific functions necessary to support the QR integration operations. These were organized into the work breakdown structure shown in Figure 4.

| QUICK-REACTION PAYLOAD<br>CHECKOUT & INTEGRATION OPERATIONS |  |  |  |  |  |
|---|--|--|--|--|--|
| QRI<br>PLANNING<br>& CONTROL                                | INTEGRATION<br>ENGINEERING               | EXPERIMENT UNIT<br>MAINTENANCE &<br>MODIFICATION | EXPERIMENT<br>INTEGRATION<br>& TEST              | EXPERIMENT<br>SOFTWARE<br>INTEGRATION                      | QR<br>MISSION<br>INTEGRATION                       |
| PLANNING  | ANALYSIS                                 | SUBSYSTEM<br>MAINTENANCE                         | INTERFACE<br>HARDWARE                            | SPACELAB<br>DMS SIMULATION                                 | FLIGHT<br>ASSIGNMENT                               |
| SCHEDULING  | DESIGN                                   | SUBSYSTEM<br>TEST & C/O                          | FABRICATION                                      | DEVELOPMENT &<br>MAINTENANCE                               | ANALYSIS<br>SUPPORT                                |
| CONFIGURATION<br>CONTROL                                    | SAFETY &<br>COMPATIBILITY<br>SPEC REVIEW | MODIFICATION                                     | HARDWARE<br>INSTALLATION                         | P1 SOFTWARE<br>DEVELOPMENT                                 | EXPERIMENT<br>FLIGHT<br>OPERATIONS<br>REQUIREMENTS |
| DOCUMENT<br>CONTROL   | TEST<br>REQUIREMENTS                     |  | INTEGRATION<br>& TEST                            | LIAISON  |  |
| ADMINISTRATION  | ENGINEERING<br>LIAISON                   |  | DATA ANALYSIS<br>& EVALUATION                    | SHUTTLE FLIGHT<br>SOFTWARE<br>LIAISON                      | EXPERIMENT<br>FLIGHT<br>OPERATIONS<br>PROCEDURES   |
| LOGISTICS   |  |  | POST-FLIGHT<br>EXPERIMENT<br>HARDWARE<br>REMOVAL | EXPERIMENT-<br>SPACELAB<br>FLIGHT SOFTWARE<br>VERIFICATION | FLIGHT<br>OPERATOR<br>FAMILIARIZATION              |
| MISSION<br>MANAGEMENT                                       |  |  | TEST<br>PROCEDURES                               |  | MISSION PLANNING<br>LIAISON                        |

Figure 4. QRI Concept - Work Breakdown Structure

Analysis of the work breakdown structure shows a natural division between operational activities and R&D activities. Without experiments on board, the EU/Pallet have hardware and operational requirements similar to the SU. Therefore, EU/Pallet maintenance and modifications should be an extension of the SU maintenance and modification activity. Experiment operations are R&D in nature and should be performed by a dedicated Quick-Reaction Integration Activity (QRIA).

The recommended QRIA organization is shown in Figure 5. The two dotted-line groups at the left are planned elements of the Shuttle operations at the launch site and perform the operational activities. The remaining groups perform the R&D activities associated with the experiment integration. The mission managers serve as a single-point contact for the experimenters to simplify their working interfaces. A total of 62 personnel can accomplish the integration activities, assuming two flights per year. This group is composed of highly skilled, versatile engineers and technicians so that the need for formalized procedures and paperwork can be minimized.

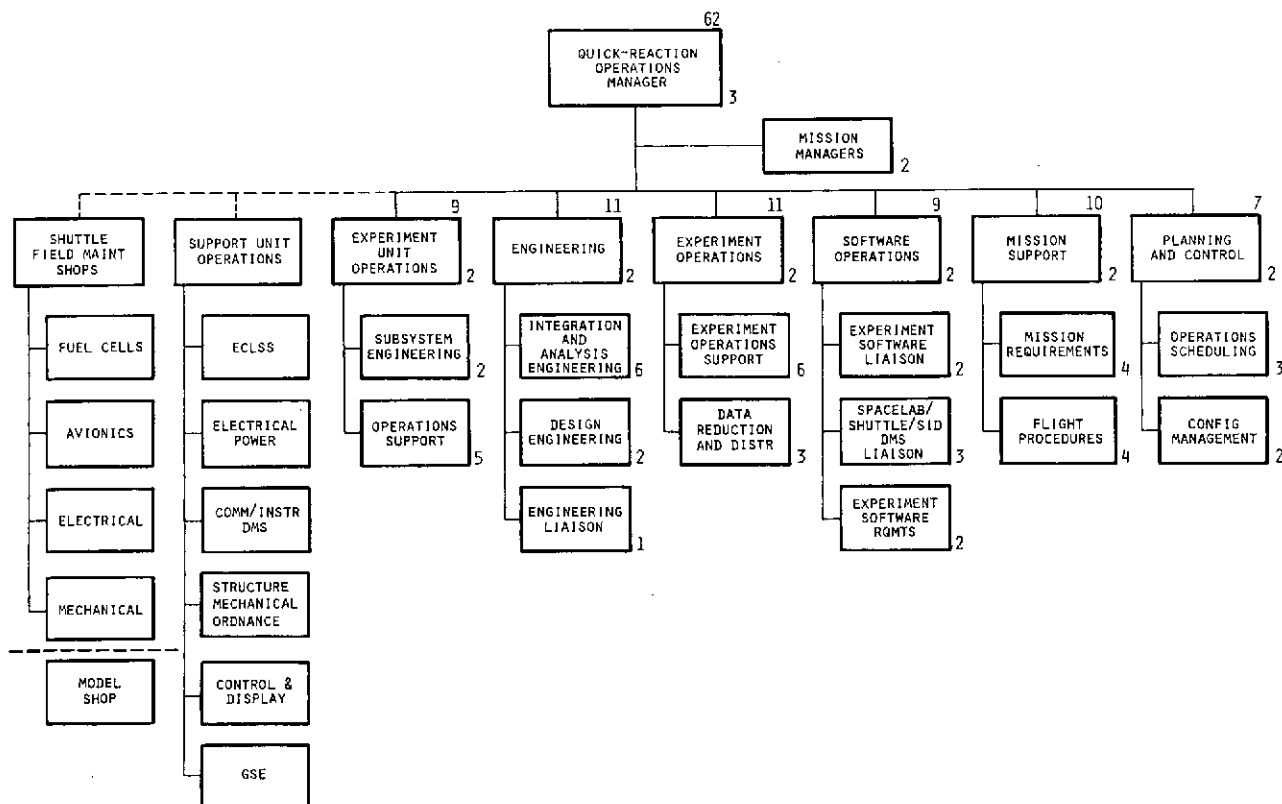


Figure 5. QRIA Organization



The integration activity can be accomplished within the existing O&C building. About 16,500 square feet of floor space is required, including the EU/Pallet work area, experimenter's labs, an environmental qualification lab, and storage area. Cost of facilities modification (in 1973 dollars) is estimated at \$700,000. An additional \$1,300,000 is required for ground support equipment, bringing the total implementation cost to \$2,000,000 (not including EU/Pallet costs).

### 3.2 SOFTWARE INTEGRATION

Many Quick-Reaction experimenters may wish to utilize the Spacelab Data Management System (DMS) to provide command, control, monitor, recording, and downlink functions. To accomplish this, the necessary experiment software must be compatible with the DMS, thus requiring a software integration process. The study objectives were to identify software integration criteria for both the experimenter and the overall software integration process, and then to update the software integration concepts developed in the initial study.

The Spacelab DMS<sup>1</sup>, shown in Figure 6, provides the following from the user's point of view:

- Standard digital interface to the DMS computer via Digital Interface Units (DIU)
- A dedicated hardwire interface to the Data Exchange Control Unit (DECU) for high data flow requirements
- Analog interfaces via dedicated cables with standard impedance and voltage
- Analog and digital tape recording capability
- Command, control, and monitoring via three, multifunction cathode ray tube displays
- Two-way interface with the Orbiter for selected monitoring and communication with the ground and other external systems

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<sup>1</sup>It should be noted that recent Spacelab DMS concepts include separate computers for experiment control/monitoring. The advent of a dedicated experiment computer is not thought to materially affect the Quick-Reaction software integration criteria presented in this report.

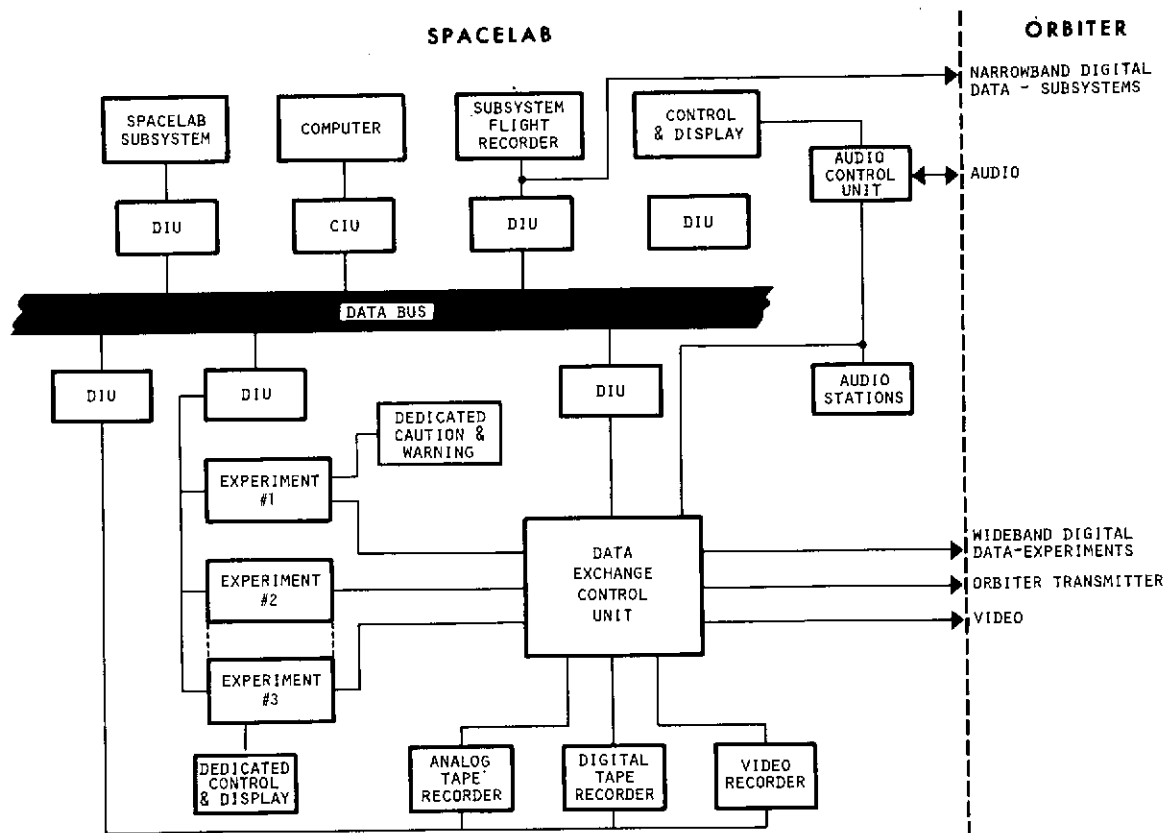


Figure 6. Spacelab Data Management System

The principal experiment/DMS interfaces are shown in Figure 7. As shown, the primary software interface is with the DMS computer. The extent of this

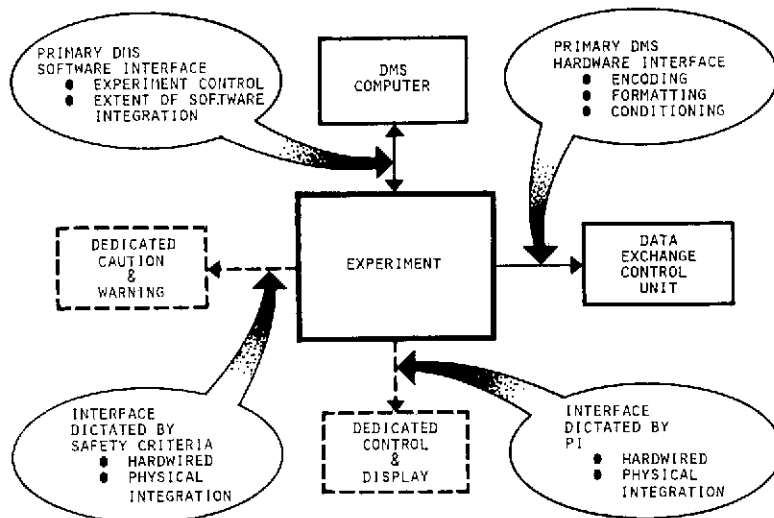


Figure 7. Experiment/DMS Interfaces

interface and the resulting software integration job and its complexity will be determined by the degree of experiment control and experiment data control required by the particular QR experiment. To keep the software integration within the QR concept, the following interface criteria were defined:

#### Experiment/DMS Computer Interface

- Degree of control shall be limited to that achieved through the real-time acquisition of discrete events data and digital data; the processing of that data; and the issuance of discrete, functional commands.
- Displays shall be limited to presentation (alphanumeric/graphical) of current operation experiment data for control/monitoring purposes.
- DMS computer shall not provide a scientific/engineering analysis capability.
- Degree of experiment checkout, fault detection, and isolation shall be limited to normal control of equipment configuration; the initiation of built-in self-tests; and the acquisition and display of resulting data.

#### Experiment/DECU Interface

- Experiment digital data shall be encoded and formatted to be compatible with the Orbiter transmitter.
- Experiment analog signals shall be conditioned to be compatible with Orbiter avionics - the DECU shall provide for communication and sub-carrier oscillators compatible with Orbiter transmitter circuitry.

To accomplish the software integration, it was assumed that a DMS software group will exist as part of the SU/EU operational activity (i.e., not part of the QR activity). This group will maintain the DMS software; perform all operational software process activities related to design, coding, testing, and integration; demonstrate that experiment software meets user requirements; and perform prelaunch compatibility demonstration.

The experimenter provides experiment control requirements based on the DMS utilization criteria. He then monitors the software development for his experiment, certifies that it satisfies acceptance test criteria, monitors the integration process, and participates in the prelaunch checkout process to provide continued assurance of experiment and experiment control readiness in the Shuttle environment.

This software integration concept stresses user participation and simplicity while at the same time providing adequate assurance of compatibility and, possibly with some modification, appears to be applicable to other Spacelab missions.

### 3.3 MISSION INTEGRATION

Mission integration is the process by which the experiment operational requirements are translated into a detailed mission plan which assures that experiment objectives will be met. Experiment operational requirements include such items as: position, attitude, timing, stability, pointing, targets, RF coverage, and telemetry. The mission plan includes such elements as: launch time, trajectories, experiment schedules, attitude profiles, ground track, target availability, operating procedures, and timelines.

The Quick-Reaction user's role in mission integration is shown in Figure 8. Upon receiving an Announced Flight Opportunity (AFO) or perhaps earlier, the user submits his experiment proposal to a sponsor for funding. Using the guidelines defined in the Quick-Reaction User's Guide, he submits his experiment requirements and flight requirements to an Experiment Selection Committee. Upon committee approval, a flight assignment is made, and the user's requirements are entered into a mission planning function. In the meantime, the user may be developing his hardware for shipment to the launch site.

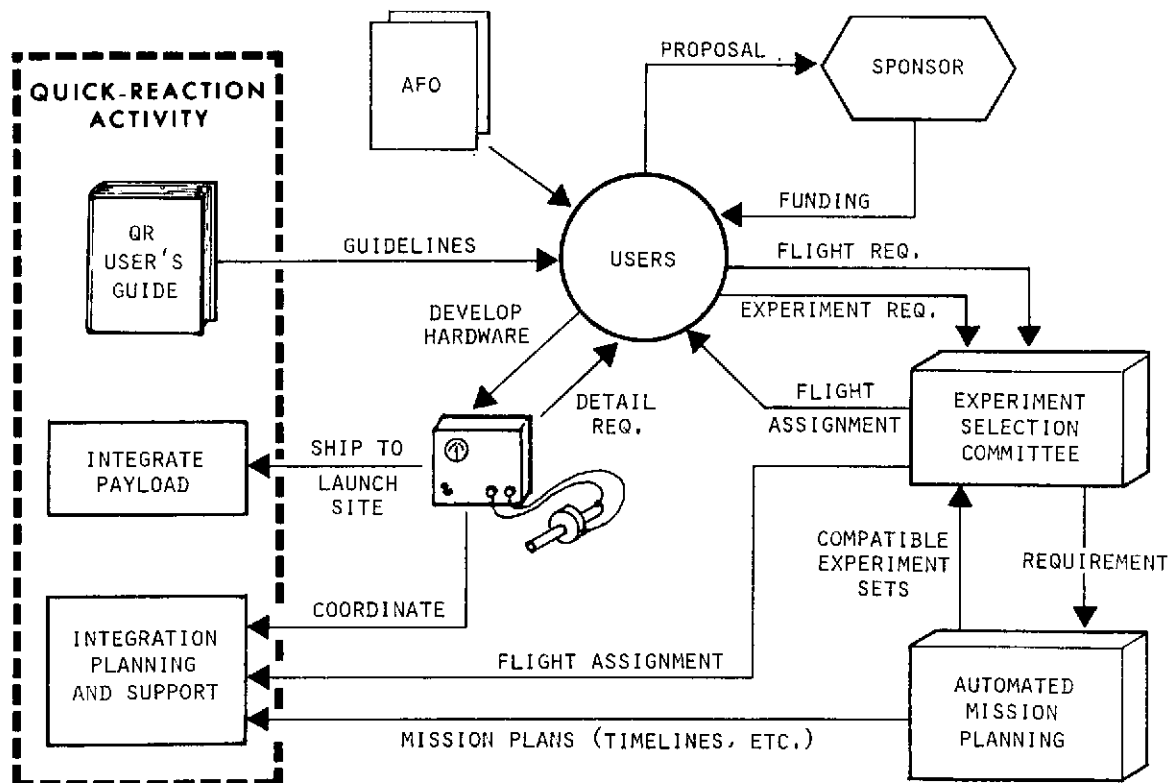


Figure 8. Mission Requirements Integration Flow

The mission planning function selects a specific set of experiments to fly on a given mission from a roster of available experiments. The selection criteria are principally concerned with compatibility of experiment requirements; that is, the several experiments selected for a flight must have requirements which are sufficiently similar so that all experiment objectives can be met.

Because the mission planning function is very complex, a high degree of automation is required to meet the QR schedules. Submission of final experiment requirements to mission planning nominally should occur about six months prior to launch, but the process must allow for iteration of mission plans up to one month before launch. Several efforts are now underway within NASA to streamline the mission planning function for the Shuttle era. It is assumed that these will result in a process that will satisfy the QR requirements.

### 3.4 CONFIGURATION MANAGEMENT

The configuration management problem is one of defining a concept which satisfies the rigid control requirements for operational hardware, i.e., the Support Unit (SU), Experiment Unit (EU), and pallets, and, at the same time, allowing flexibility and simplicity for the experiments. The system should allow configuration changes to be initiated internally by the Quick-Reaction activity and by the carrier development center. Both permanent and temporary changes must be processed. Finally, the concept must be compatible with overall Shuttle configuration management planning.

The approach used to develop the configuration management concept is shown in Figure 9. Principal inputs were the Shuttle Level II requirements, the Atlas-Centaur plan, and an airline plan. The latter two are examples of effective programs which are currently operational and provided the basis for developing a QR concept which is consistent with the Shuttle Level II requirements.

For the SU, it is recommended that configuration be maintained in the same manner as for the Shuttle vehicle. The dominant reason is that this is an operational unit committed to various missions, including the QR mission. This approach avoids separate procedures and it satisfies KSC guidelines for launch center operational responsibility.

For the EU/Pallet, configuration need not be maintained as rigidly except where safety and SU interfaces are involved. The EU will be operated and

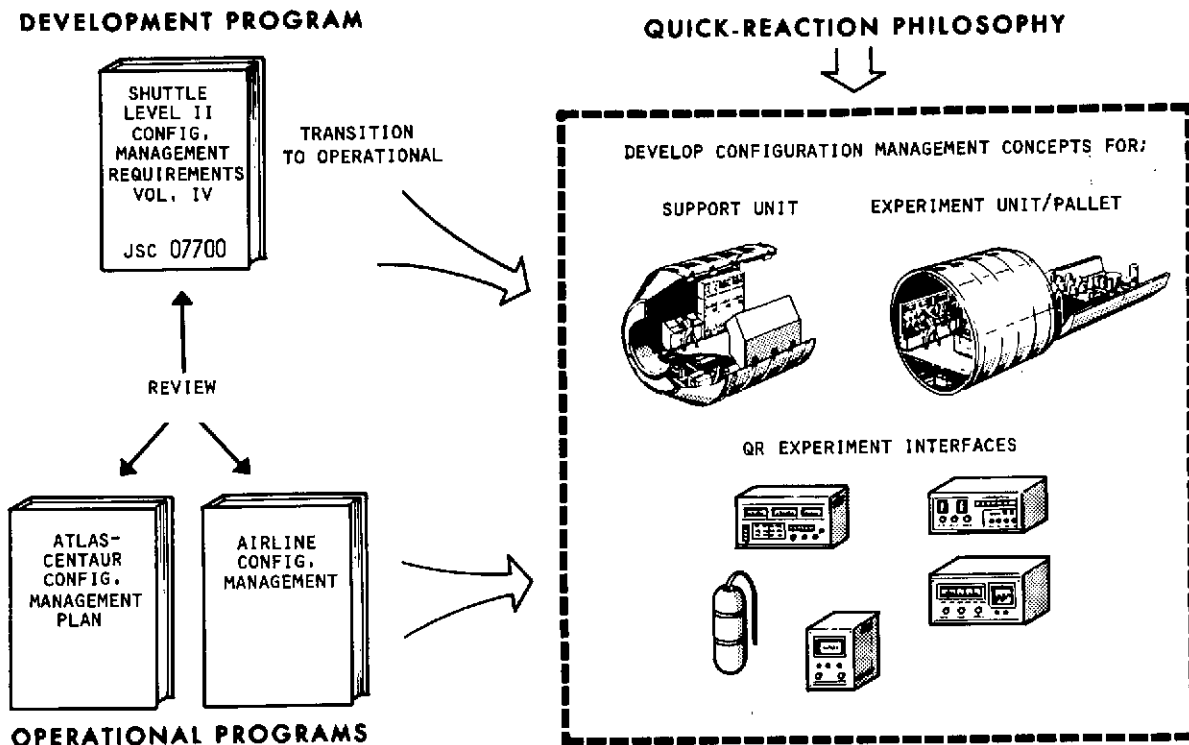


Figure 9. Approach to Developing the Configuration Management Concept

maintained exclusively by the QRIA, so that its configuration control can be vested within the QR organization.

Since the EU/Pallet will usually carry a different complement of experiments on each mission, some reconfiguration will be required prior to each flight. Some of this reconfiguration may be permanent, and some temporary. For QR purposes, a temporary configuration change is defined as one which is effective for a single mission only.

The permanent change flow is shown in Figure 10. Change requests may be initiated either by the QRIA or by the development center. The Configuration Committee which approves changes is composed of representatives from each element of the QR organization plus Safety. The dashed lines show that status information is provided to the Planning and Control function at nearly every step of the flow. This is a formal procedure with all permanent changes well documented with respect to justification, technical/design adequacy, fabrication/installation correctness, and handbook update requirements.

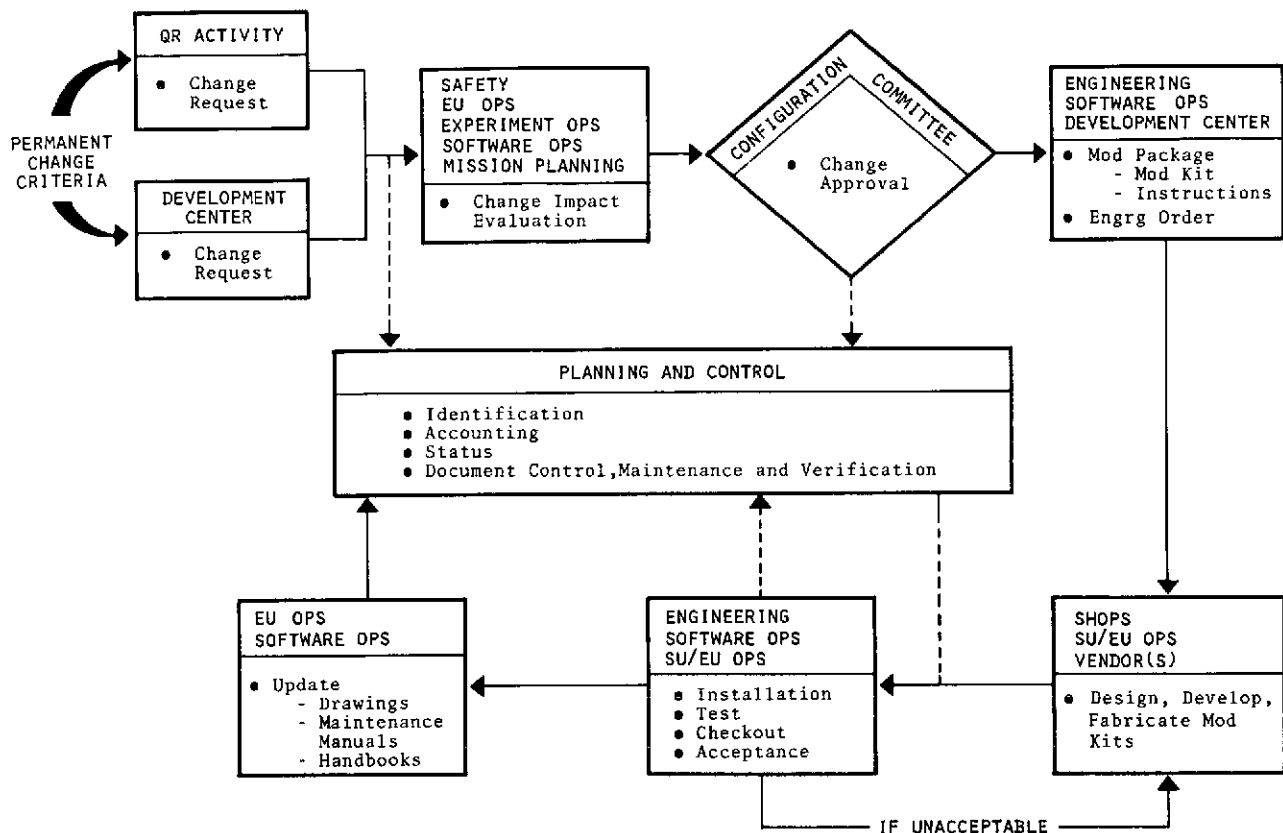


Figure 10. Experiment Unit Permanent Change Flow

The temporary change flow is shown in Figure 11. Here the user may initiate a change request. The QR Mission Management approves changes, subject to concurrence by Safety and to review by the Configuration Committee. Consistent with the QR philosophy, the QR Mission Manager also relieves the experimenter from the need to closely monitor detailed activities not directly concerned with the actual operation/performance of his hardware. This is largely an informal procedure in which documentation is minimized and formal control is maintained only where safety and Orbiter compatibility are of concern.

Experiment hardware configuration is controlled only for safety and interface compatibility. The User's Guide defines functional interfaces and safety requirements. If the user requires a change, he provides the necessary interface and safety data to the QR Mission Manager. The QR Mission Manager approves significant changes and initiates the change processing.

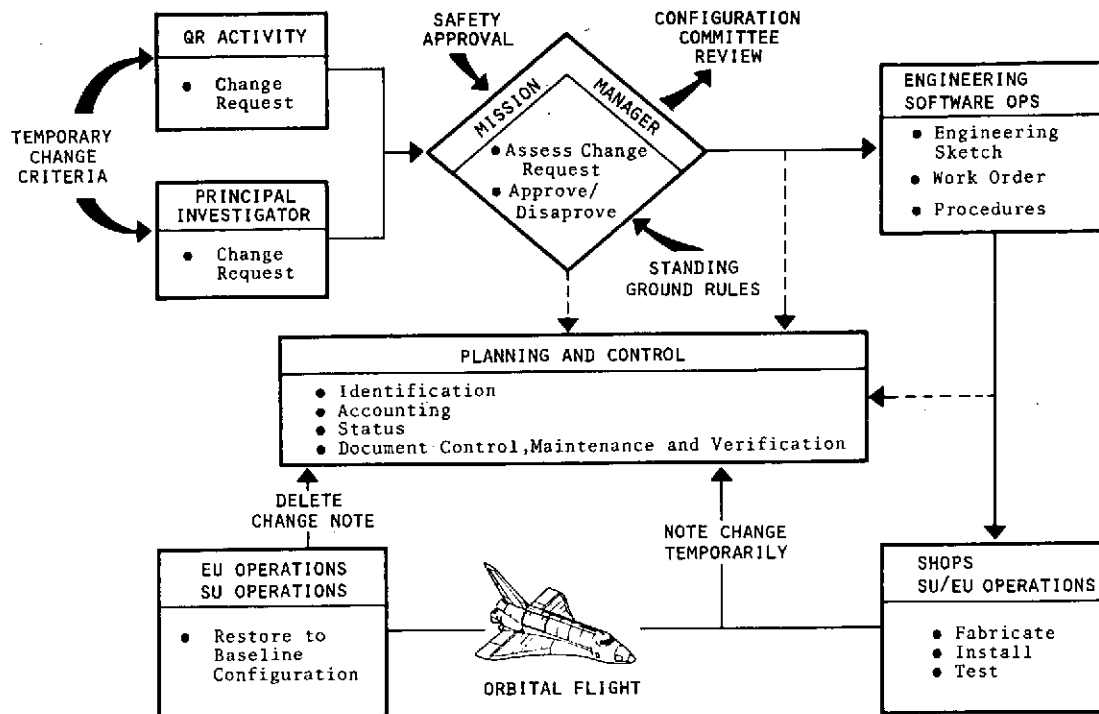


Figure 11. Experiment Unit Temporary Change Flow

### 3.5 DOCUMENTATION

The documentation concept defined in this study represents a major departure from existing Space Program documentation systems. The principal differences are in the use of the Quick-Reaction User's Guide and in the role of the QR Mission Manager. Every effort is made to make the system as simple as possible from the user's point of view, and to retain as much informality as possible. At the same time, all essential functions of a conventional documentation system are retained.

The QR requirements documentation flow is shown in Figure 12. The User's Guide, prepared by the QR activity, provides the user with all information he needs. It describes the Shuttle Program, the QR mode, Spacelab and its subsystems, policies, and procedures. It delineates facilities, interfaces, safety specifications, quality requirements, and schedules. It provides guidance for experiment design and integration requirements. Finally, it provides tear-out sheets and special forms which the experimenter may use to submit his requirements.

The QR Mission Manager provides direct, informal support to the user to assist him in every way necessary. He also provides a single-point interface



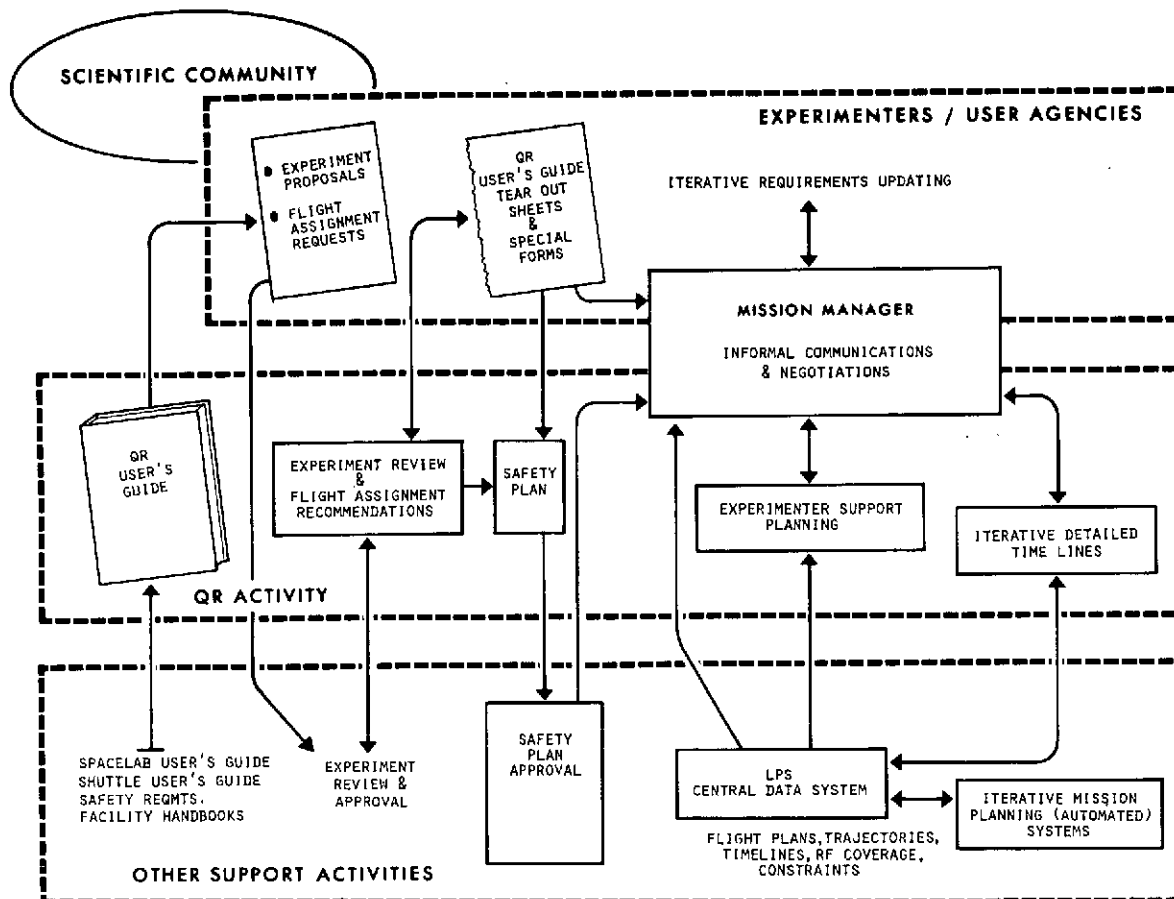


Figure 12. Quick-Reaction Experiment Requirements Flow

for the user with the QR activity and other support activities. This approach relieves the user of otherwise burdensome documentation requirements and minimizes his working interfaces.

### 3.6 EQUIPMENT POOL

An added service which the Quick-Reaction activity might provide to the user is an equipment pool. As shown in Figure 13, this pool stocks a variety of general - purpose mission equipment and support hardware that is available to the user on request. The rationale for the pool is that many users will have common requirements, and hence a significant cost saving will result. The objectives in this study were to define the pool concept and

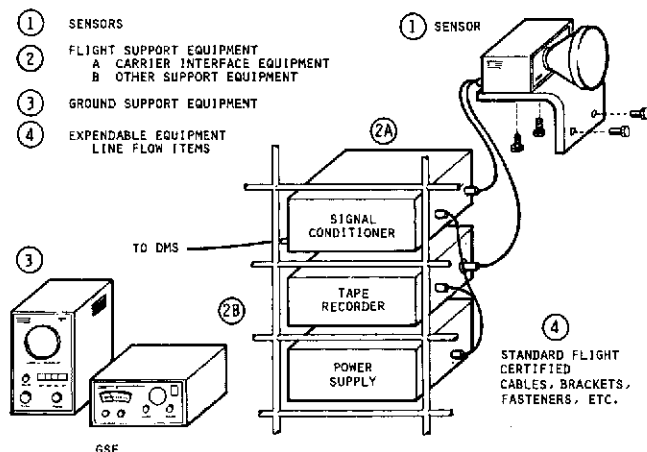


Figure 13. Types of Pooled Hardware

to identify any problems and tradeoffs.

The pool concept is shown in Figure 14. The User's Guide lists available equipment which can be requested by means of tear-out sheets. The equipment may be sent to the user's home laboratory for his use in experiment development, or it may be used only at the launch site. An example of the latter might be a flight-certified gas bottle which is required for flight but not for use in the laboratory. Most experimenters will require such equipment as standard mounting racks and brackets. After flight, the equipment may be returned directly to the pool, or to the user's home laboratory, if required for final calibration or data control.

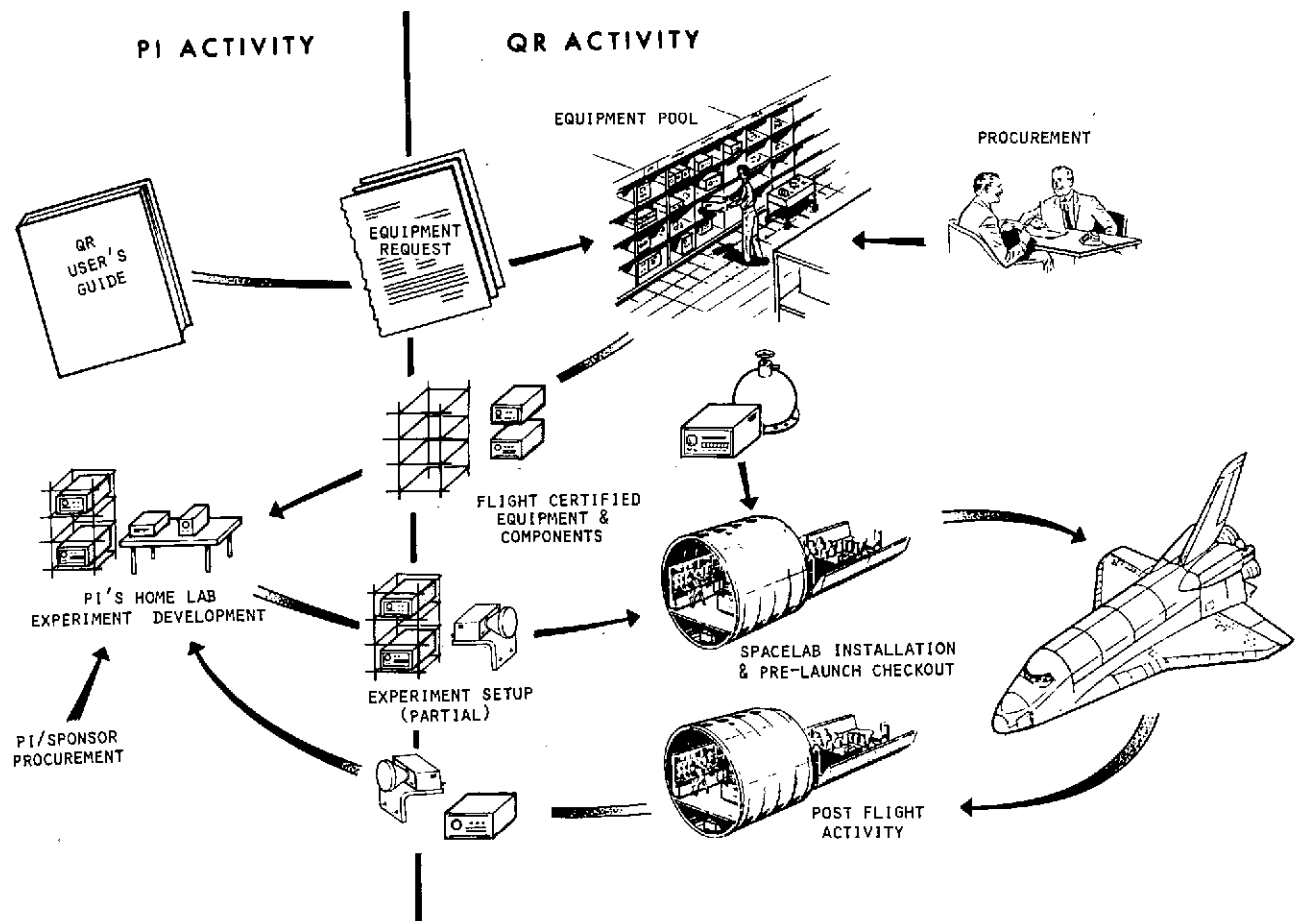


Figure 14. Equipment Pool Procedures

Further evaluation of the pool concept is recommended, principally to determine if the pool should be exclusive to the QR program or should service all payload programs. The more detailed evaluation also would establish equipment selection criteria, methodology for cataloging, scheduling and loan proce-

dures, and a maintenance approach. Other considerations are cost allocation, integrity maintenance of flight-certified hardware, priorities, and liabilities. These latter considerations become significant where high-cost equipment may be used for extended periods at the user's home laboratory.

### 3.7 INTEGRATION ALTERNATIVES

The baseline Quick-Reaction concept developed in this study assumes that the integration activities take place at the launch site. Other location options were considered and qualitatively evaluated.

For this analysis, four levels of integration, shown in Figures 15 through 18, were defined as follows:

#### Level IV - Instrument Assembly Integration

Assembly of individual instruments and their unique support subsystems into a compatible package of equipment to accomplish specific mission objectives.

#### Level III - Instrument to Supporting System Integration

Integration of one or more instrument assemblies with Spacelab elements:

- A. Instruments into racks or on pallets
- B. Racks into rack sets or pallets into pallet sets

#### Level II - Spacelab Elements into Cargo Integration

Assembly of Spacelab elements into a cargo for a single Shuttle flight:

- A. Rack set to experiment section
- B. Rack set to support section; experiment section to support section; pallet set to integrated pressurized section; Spacelab to general purpose mission equipment

#### Level I - Cargo-Shuttle Integration

Integration into the Orbiter of everything that goes on a single Shuttle flight:

- A. Total cargo to Orbiter simulator
- B. Total cargo to Orbiter

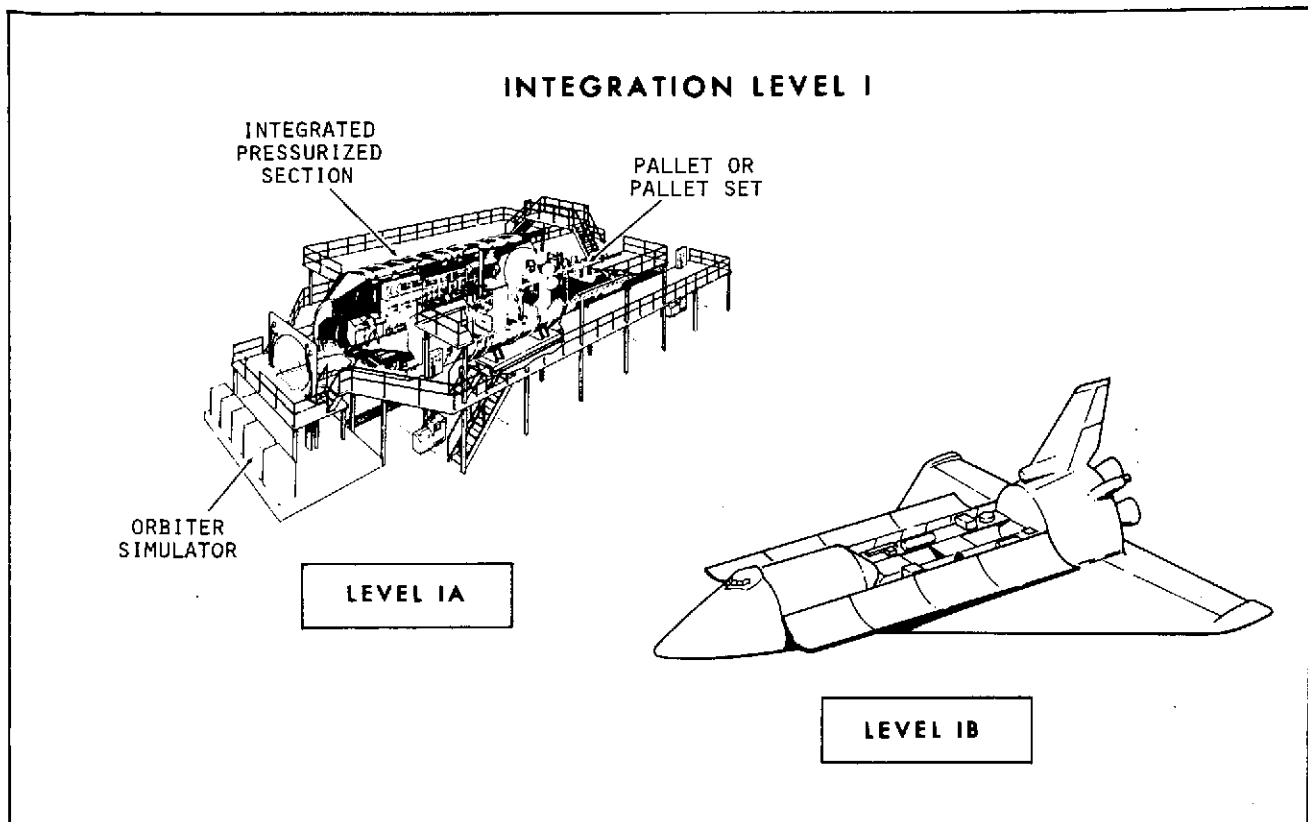


Figure 15. Level I Payload Integration

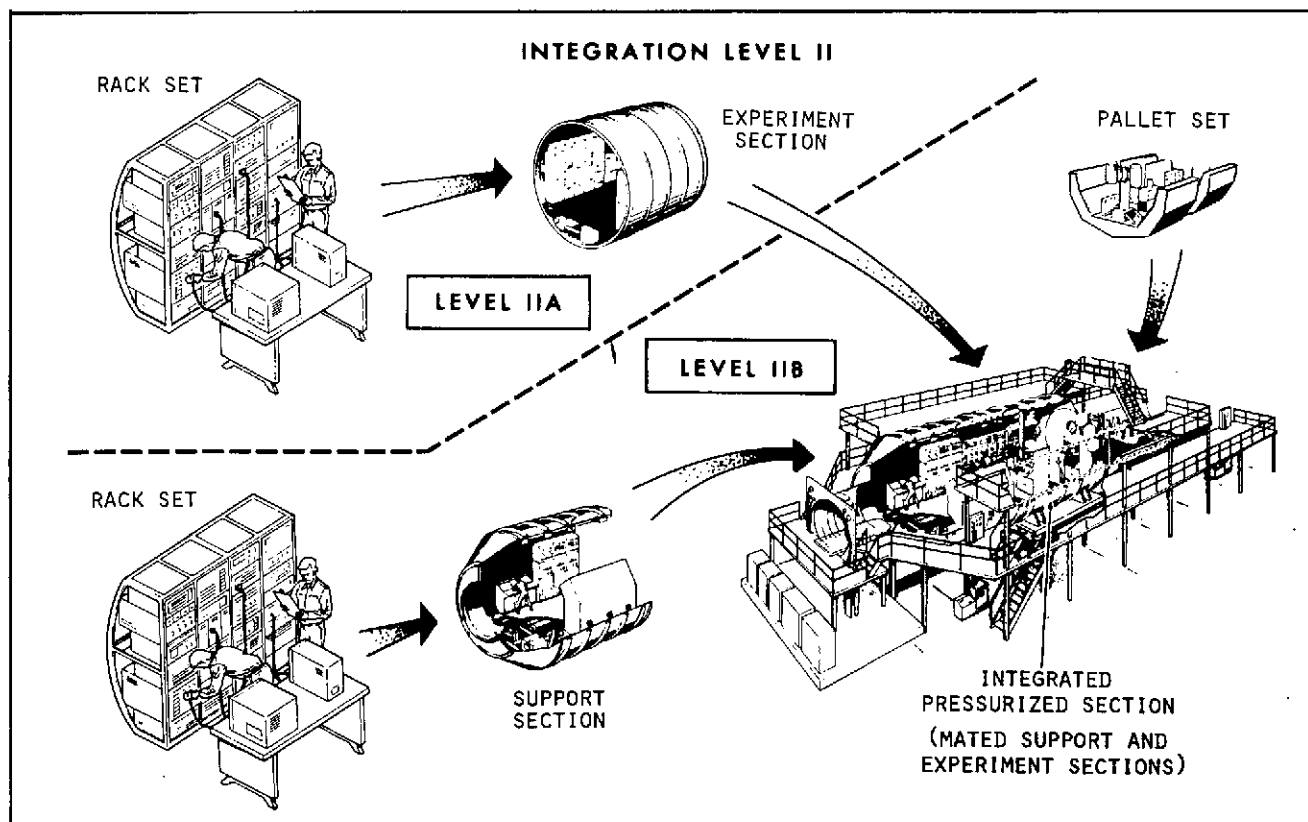


Figure 16. Level II Payload Integration

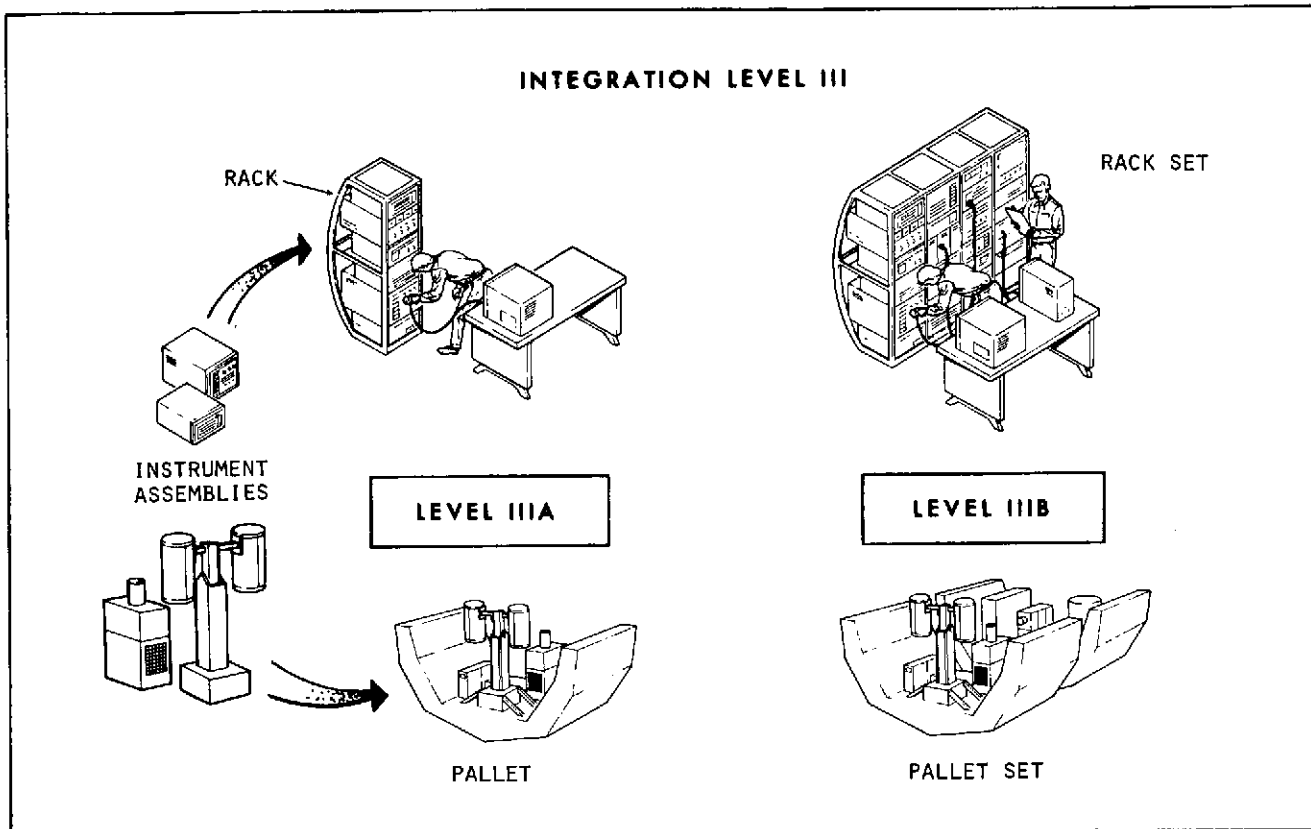


Figure 17. Level III Payload Integration

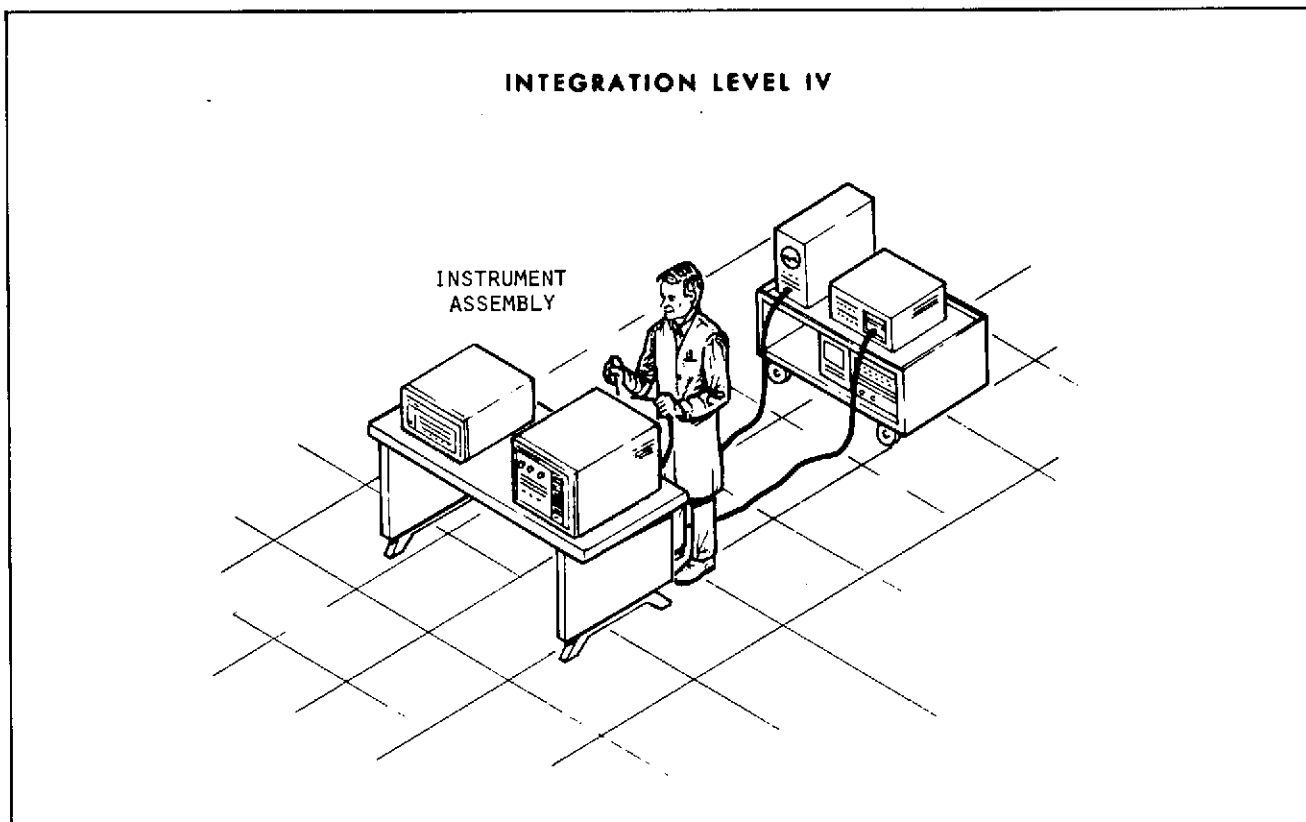


Figure 18. Level IV Payload Integration

In addition to the launch site, a development center and a central integration site were considered as location alternatives. Noting that Levels IIB and I must be performed at the launch site, the five options shown in Figure 19 were developed. The factors considered were:

Performance

- User oriented approach
- Use of existing skills and experience

Schedule

- Processing time
- Contingency recycle time
- Orbiter impact

Costs

- Facilities/equipment
- Manpower
- Transportation

Management

- Documentation
- Organizational interfaces

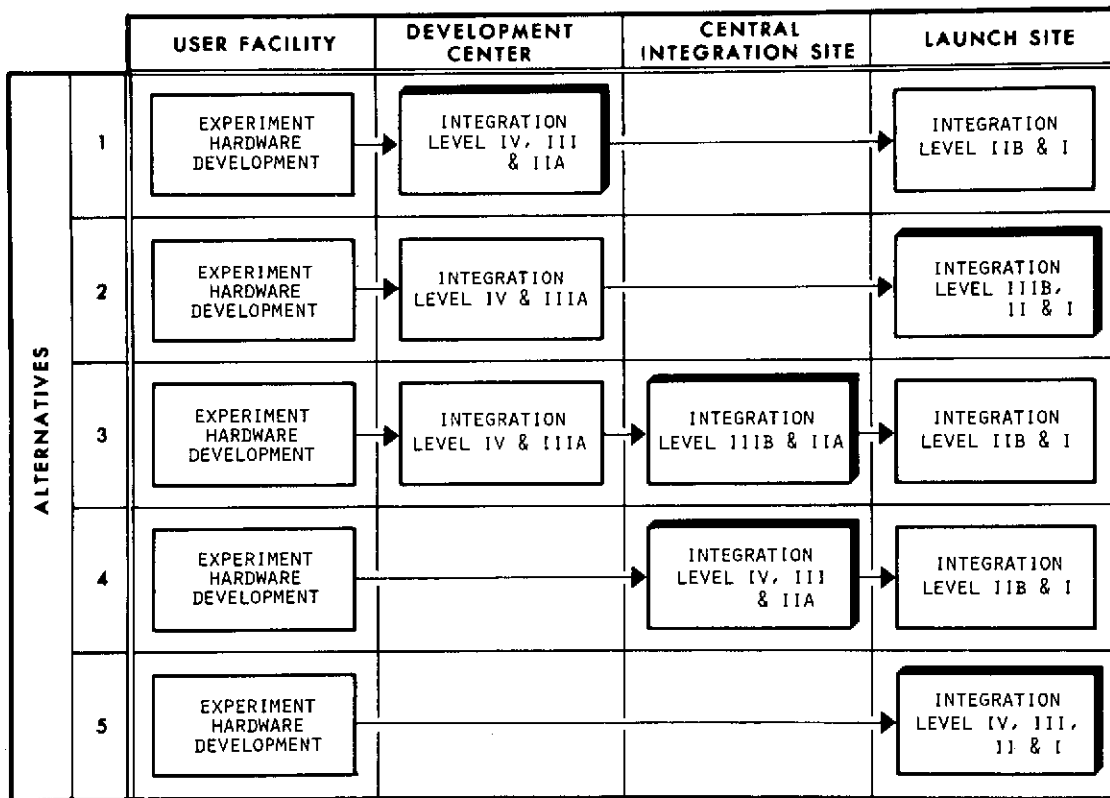


Figure 19. Quick-Reaction Integration Alternatives

The conclusions drawn from this analysis are:

- Cost and schedule differences between alternatives are of secondary importance when viewed from the user and programmatic perspectives. This results from the modularity of the Spacelab which allows convenient air shipment of racks and modules. This conclusion is substantially different from the first study in which a unitized Sortie Lab was used.

- Performance and management objectives are best met by accomplishing all integration at a single location. This is because the user works at only one location, and the problems of hardware turnover are minimized.

#### 4.0 IMPACT OF A SECOND LAUNCH SITE

Because of the significantly different operational environment at the Western Test Range (WTR), a separate analysis was performed to estimate the impact of the Quick-Reaction mode on WTR. The existing WTR operational plans were reviewed, QR operational flows were developed, and QR requirements were defined in the context of WTR capabilities. The effects on transportation, facilities, equipment, and manpower were estimated.

The following assumptions were made with respect to the WTR operating environment in the Shuttle era:

- The Air Force will be responsible for Shuttle operations, including Level I integration.
- The resident NASA-WTR organization will operate in its traditional WTR host role, as it does currently for unmanned launches.
- Non-DOD payloads will be processed by owner/operators using transient crews.
- The payload integration facility proposed for WTR will accommodate Spacelab processing.
- A Spacelab Support Unit and its associated GSE will be permanently assigned to WTR to accommodate all Spacelab missions and will be shared by the QR missions.
- A transient KSC Spacelab ground crew will perform Support Unit maintenance, mating, and final Spacelab checkout.

In addition, it was assumed that all four levels of integration would be performed at WTR, maintaining all of the basic features of the QR concept.

Within this framework, the principal issue is whether the Experiment Unit/Pallets and supporting equipment should be permanently assigned to and located at WTR or permanently based at KSC. In the first case, the added cost of the flight hardware, support equipment, and storage space contributes to higher initial cost. In the second case, shipping the equipment to WTR for each flight contributes to higher operational cost, but it can also be used for flights from KSC.

Both options are technically and operationally feasible. The relative costs depend on WTR mission frequency. Both options should be kept open until this is determined.

Since it is assumed that the proposed payload integration facility for WTR will accommodate Spacelab processing, the impact on WTR facilities is minimal. Existing laboratory space, engineering offices, and shop facilities are adequate. Modifications to clean rooms and other specialized facilities may be required.

Impact on support equipment also depends on mission frequency. Options are: ship existing equipment from KSC as needed; buy new equipment for WTR; share equipment with other WTR Spacelab programs. The most likely solution is some combination of these.

With low flight density, a transient crew from KSC for each flight provides the most efficient manpower utilization. This avoids much duplication, as most of the planning and paperwork can be done at KSC by the QR organization. About 33 transient personnel are required for each launch. If launch density increases, a combination of resident and transient crew would be more efficient.

The principal conclusions derived from this analysis are that the QR concept can be implemented at WTR, and the frequency of QR missions will be the driver in selecting the best of several viable operating modes.

## 5.0 MISSION FEASIBILITY

Mission feasibility is concerned with the question of benefits versus cost.

The most significant benefit of the Quick-Reaction concept is that it increases the potential Shuttle user market by providing a service which:

- Provides rapid "concept-to-data-return"
- Places minimum formal requirements on the users
- Provides an economical means for certain low-budget users to participate in the Space Program.

This is accomplished by accommodating only simple-to-integrate experiments and providing a dedicated "Quick-Reaction" integration capability for this class of experiments.



The cost of implementing the concept, using the split-module Spacelab as experiment carrier and assuming two flights per year, is summarized as follows:

| <u>Fixed Costs</u> |            | <u>Recurrent Costs</u> |            |
|--------------------|------------|------------------------|------------|
| EU and Pallets     | \$4.55M    | QR Organization        | \$1.72M/Yr |
| GSE                | 1.30       | (62 people)            |            |
| Facilities         | <u>0.7</u> |                        |            |
|                    | \$6.55M    |                        |            |

These costs are based on 1973 dollars. Only dedicated resources are included. The Support Unit is not included as it is shared with other missions. Shuttle launch costs are not included.

Using this data, and assuming about 9 to 11 experiments per flight, integration costs are quite low - less than \$100K per experiment. If Shuttle launch costs are included, the flight cost per experiment will be an order of magnitude higher.

Thus, the baseline concept developed in this study provides a user-oriented, low-integration-cost service; however, the relatively high flight cost per experiment may discourage low-budget users. Another operational mode, the "space-available" concept, is more cost effective.

## 6.0 THE SPACE-AVAILABLE CONCEPT

Many Shuttle payloads will not use all of the Orbiter capabilities. This provides an opportunity to fly additional payloads on a "space-available" basis, sharing the launch costs with the primary payload. These additional payloads can be integrated on a Quick-Reaction basis.

"Space available" is defined as Orbiter capability remaining after all primary payload requirements are satisfied, and includes:

- Volume
- Weight
- On-orbit time
- Crew time
- Electrical power
- Thermal control
- Data management
- Communications
- CG margin

Space may be available on a planned basis; that is, derived from the Traffic Model and firmed up as the primary payload is defined. It also may

be available on a contingency basis; that is, in a multiple-element payload, one element may slip in schedule, but the others must fly on schedule. Analysis of the October 1973 Traffic Model shows that 23 percent of the Shuttle flights could carry a planned space-available payload 10 feet in length and weighing up to 3000 pounds. Thus for a relatively small increment in flight cost, the potential exists for providing large scientific returns.

In the planned mode, the available space is earmarked relatively early in the development cycle, but the space-available payload is integrated in the QR mode. This provides the low-cost and schedule benefits to certain users.

In the contingency mode, two options are available:

Option A: A pre-integrated payload is built up, tested, and held on a standby basis. This provides very rapid availability of a substitute payload but, because the primary payload and mission parameters are not known during buildup, experiment selection is necessarily very restricted.

Option B: A QR payload is built up for a specific mission. Although this option requires more time to respond to a primary payload failure, it also allows more efficient use of the available space and broader spectrum of experiments.

A key difference between the space-available and the dedicated QR modes is that the experiment complement must now be selected to be compatible with primary payload mission parameters. Furthermore, the space-available payloads must have minimum interference with the primary payloads.

An overview of the space-available concept is shown in Figure 20. Candidate experiments are defined and logged in a data bank. When space availability is identified, experiments are selected which are compatible with primary mission parameters. These experiments are combined into appropriate space-available configurations. Selection of the specific flight configuration is based on optimum use of the available space and perhaps also other criteria such as scientific merit of the experiment complement. Once the flight configuration is selected, the integration process proceeds in much the same manner as the previously defined QR integration.

In the planned mode, ample time normally is available to develop an experiment complement which makes optimum use of the available space. Several configurations may be developed and tested against appropriate selection criteria. In the contingency mode, failure of a primary payload element can occur as late as 10 weeks prior to launch and a space-available payload can be integrated into it, but the opportunity to define an optimum payload is limited.

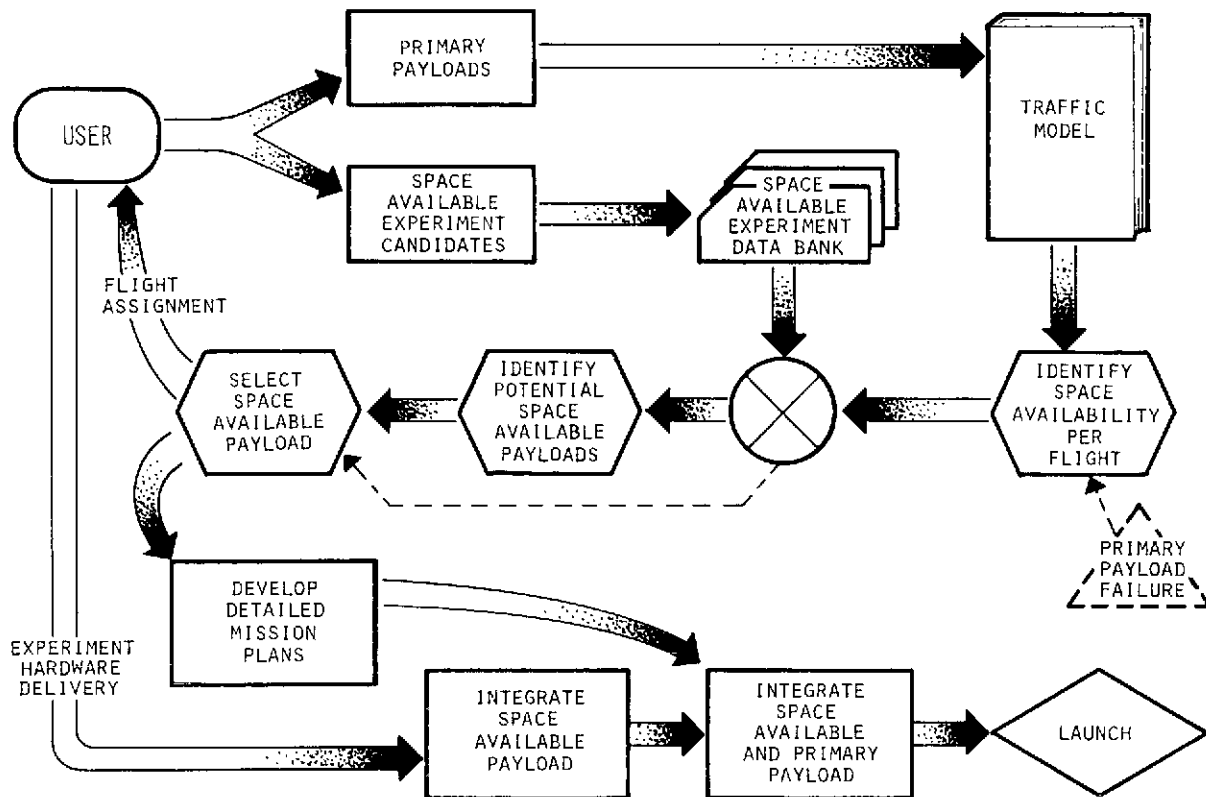


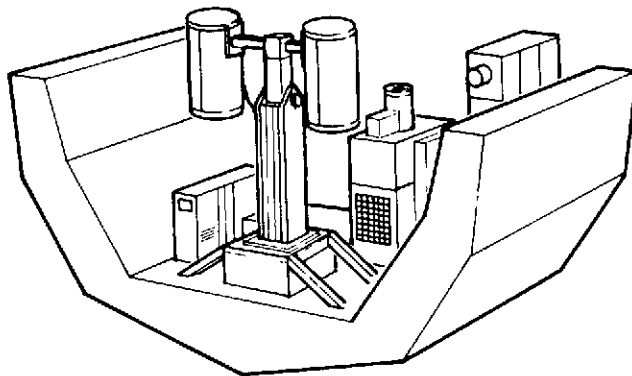
Figure 20. Space Available Concept Overview

To test this concept, a specific case was analyzed in detail. The primary mission selected was Astronomy Mission AST-1A, which delivers an Explorer to a 297-mile orbit, and retrieves two life sciences modules from a 300-mile orbit. This mission allows a space-available payload weight of 9700 pounds and provides over two days of experiment operations. The space-available configuration selected, shown in Figure 21, uses a Spacelab pallet section as a carrier and carries four earth-observation-type experiments.

This analysis developed the integration and checkout requirements, ground operational flows, a mission profile, and resource requirements. The analysis results led to the following conclusions:

- Space-available is the most cost-effective way to implement the QR concept.
- Both the planned and the contingency modes should be retained as space-available options.
- The standby mode is not suitable for QR space-available.

- Resource requirements are essentially similar to the dedicated QR mode. Manpower requirements will depend on flight density.
- Quick-Reaction space-available payload development should not begin too early - a "domino" effect will occur due to primary payload changes, mission planning will be iterated unnecessarily, and the experimenter's involvement will be unnecessarily long.



#### DESCRIPTION

- WEIGHT: ~1400 POUNDS (640 KG)  
EXCLUDING EXPERIMENTS
- WIDTH: FULL PAYLOAD BAY
- LENGTH: ~10 FEET (3 METERS)
- STANDARD PAYLOAD SUPPORT  
SYSTEMS INTERFACE
- ONBOARD THERMAL CONTROL,  
DATA LINK, AND ELECTRIC  
POWER DISTRIBUTION  
SUBSYSTEMS
- WALK-ON CAPABILITY

Figure 21. Spacelab Pallet Section for Space Available

Further development of the space-available concept should consider flight modes other than the sortie mode; for example, the development of a QR free-flier may be feasible and cost effective. Other aspects to be considered include: the concerns of the primary payload owner; the liability aspects; and cost-sharing criteria. Finally, a more detailed investigation of automated mission planning techniques should be made to assure that the necessary flexibility can be provided.